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ERAWATCH Analytical Country Report 2007: Germany

Alexander Grablowitz, Jan Nill

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Executive summary

Research-related policies aimed at increasing investment in knowledge and strengthening the innovation capacity of the EU economy are at the heart of the Lisbon Strategy. The strategy reflects this in guideline No. 7 of the Integrated Guidelines for Growth and Jobs which aims to increase and improve investment in research and development, in particular in the private sector.
To support the mutual learning process and the monitoring of Member States efforts, one task of JRC-IPTS within ERAWATCH is to produce analytical country reports. The main objective is to characterise and assess the performance of national research systems and related policies in a structured manner that is comparable across countries. In order to do so, the system analysis focuses on key processes relevant for system performance. Four policy-relevant domains of the research system are distinguished, namely resource mobilisation, knowledge demand, knowledge production and knowledge circulation. This analytical approach has been tested in 2007 by applying it to six countries, one of which is Germany. This report is based on a synthesis of information from the ERAWATCH Research Inventory and other important available information sources.

Germany has a highly developed and well functioning research system, as the following overview of strengths and weaknesses shows.

Domain	Challenge	Assessment of system strengths and weaknesses
Resource mobilisation	Securing long-term investment in research	Stable mechanisms to ensure long-term research funding, but multi-level negotiations for increases are time-consuming and require political majorities difficult to achieve
	Dealing with barriers to private R&D investment	The two-thirds share of private R&D funding meets Lisbon objectives
	Providing qualified human resources	Functioning mechanisms for the provision of a strong human resource base for R&D with declining S&T graduate basis but increased attractiveness of research careers
	Justifying resource provision for research activities	Well established justification in terms of preserving economic competitiveness through S&T did not prevent declining share of R&D expenses in general budget
Knowledge demand	Identifying the drivers of knowledge demand	Demand signals from classical industries well perceived by policies, but demand signals outside of these or international demand signals not well addressed
	Channelling knowledge demands	Strong R&D programme basis enables a flexible response to changes in demand
	Monitoring demand fulfilment	Well established evaluation mechanisms enable responses to changes in demand
Knowledge production	Ensuring quality and excellence of knowledge production	Mechanisms in place to enhance scientific excellence of public research through DFG and Science Council. However, the rigidity of the public research system, which is strongly geared towards traditional scientific disciplines, makes it difficult to adapt to cross-cutting opportunities
	Ensuring exploitability of knowledge	Strong focus on research closely linked to the economy's strengths
Knowledge circulation	Facilitating circulation between different research sectors	High profile of knowledge circulation measures
	Profiting from international knowledge	Number of measures and institutions in place to ensure access to international knowledge
	Enhancing the absorptive capacity of knowledge users	Broad R&D base in the private sector ensuring good absorptive capacity, but weak dynamics with regard to new private research performers and S&T graduates

In each of the main domains there are strong system responses to the respective challenges. Very often, the responses are in the form of fairly stable institutional arrangements. Any remaining weaknesses are mostly related to the adaptation and enhancement of the changes being put in place.

The governance structure reflects the high level of development and the differentiated structure of the German research system. The only area in which system weaknesses are closely related to the governance structure as such is the complicated process whereby resource mobilisation is coordinated in a federal system with shared responsibilities.

The following table presents main opportunities and threats related to recent policy dynamics. It shows that recent policies, such as the Six Billion Euro programme, the High-Tech Strategy and the Initiative for Excellence, address some of the main weaknesses of the German research system and hence help to create opportunities for its further evolution. Most aspects of the research-related Integrated Guideline of the Lisbon Strategy are addressed, from the 3% R&D intensity target, via the strengthening of centres of excellence and the reform of the public research base to the improvement of co-operation between PRO and industry. The extent of the effects of recent policies remains to be seen.

Main policy-related threats are related to the domain of resource mobilisation, where both public and private R&D funding seem still insufficient to meet the 3% target. And recent policy measures in the domain of knowledge circulation are only partially addressing weaknesses such as the seemingly stagnating absorptive capacity and recent trends such as the Europeanisation and internationalisation of knowledge production and circulation.

Domain	**Main policy-related opportunities**	**Main policy-related threats**
Resource mobilisation	- Increased volume and greater political focus on public resource mobilisation through the federal "Six billion Euro programme"	- Public resource mobilisation, in particular at the Länder level, is insufficient to meet the Lisbon target - Private resource mobilisation might not respond to increased incentives to the extent anticipated
Knowledge demand	- More effective knowledge demand through better coordination between federal actors and more holistic approaches via the High-Tech Strategy	
Knowledge production	- Improved excellence and increased international attractiveness of public research enhanced by the Initiative for Excellence and Pact for Research and Innovation	- Impulses to modernise the non-university public research organisations not strong enough to bring about significant changes
Knowledge circulation	- Further improvement of the circulation of knowledge between sectors through new measures and governance mechanism targeting co-operation between public research organisations and industry, which may also counterbalance negative effects of the changed regime of intellectual property rights	- Lack of an appropriate strategy response to the increased importance of international knowledge circulation. - Policy measures too strongly oriented towards knowledge circulation between established research organisations and firms

An analysis of recent policies in these domains has shown that, by and large, current German research policy priorities correspond to the strengths and weaknesses of the research system. As might be expected in highly developed research systems, issues of cross-domain integration play a more prominent role and are increasingly effectively addressed by the research policy mix. Examples include recent policy initiatives such as the Excellence Initiative, the High-Tech strategy and the Pact for Research and Innovation, all of which systematically link increased resource mobilisation to improvements in the co-ordination of knowledge demand, knowledge production and knowledge circulation. This is partly underpinned by new governance mechanisms like the Research Union Economy – Science which is intended to contribute to the monitoring of the High-Tech Strategy. An indicator of a cross-domain perspective is also the frequency with which cluster approaches are part of the policy measures.

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Chapter 1. Introduction

1.1 Scope and methodology of the report in the context of the European Research Area and the Lisbon Strategy

As highlighted by the Lisbon Strategy, knowledge accumulated through investment in R&D, innovation and education is a key driver of long-term growth. Research-related policies aimed at increasing investment in knowledge and strengthening the innovation capacity of the EU economy are at the heart of the Lisbon Strategy. The strategy reflects this in guideline No. 7 of the Integrated Guidelines for Growth and Jobs. This aims to increase and improve investment in research and development (R&D), with a particular focus on the private sector. One task of the JRC-IPTS within ERAWATCH is to produce analytical country reports to support the mutual learning process and the monitoring of Member States' efforts. The main objective of the reports is to characterise and assess the performance of national research systems and related policies in a comparable manner.

To ensure comparability across countries, a dual level analytical framework has been developed and applied. On the first level, the analysis focuses on key processes relevant to system performance in four policy-relevant domains of the research system:

1. Resource mobilisation: the actors and institutions in the research system have to ensure and justify that adequate public and private financial and human resources are most appropriately mobilised for the operation of the system.
2. Knowledge demand: the research system has to identify knowledge needs and how they can be met, thus determining priorities for the use of resources.
3. Knowledge production: the creation and development of scientific and technological knowledge is clearly the fundamental role of any research system.
4. Knowledge circulation: ensuring appropriate flows and distribution of knowledge between actors is vital for its further use in the economy and society or as the basis for subsequent advances in knowledge production.

These four domains differ in terms of the scope they offer for governance and policy intervention. Governance issues are therefore treated not as a separate domain but as an integral part of each domain analysis.

Resource mobilisation	Knowledge demand	Knowledge production	Knowledge circulation
• Long-term research investment • Barriers to private R&D • Qualified human resources • Justifying resource provision	• Identification of knowledge demand drivers • Channelling of demand • Monitoring and evaluation	• Quality and excellence of knowledge • Exploitability of knowledge	• Inter-sectoral knowledge circulation • International knowledge access • Absorptive capacity

On the second level, the analysis within each domain is guided by a set of "challenges", common to all research systems (see list above), which reflect conceptions of possible bottlenecks, system failures and market failures.

The way in which a specific research system responds to these generic challenges is an important guide for government action. The analytical focus on processes instead of structures is conducive to a dynamic perspective and eases the transition from analysis to assessment. Actors, institutions – and the interplay between them – enter the analysis in terms of how they contribute to performance in the four domains.

Based on the above framework, the analysis here proceeds in three steps. The first step is to analyse the characteristics of the current research system; the second step is to analyse recent changes in policy and governance. The third step in the analysis aims at an evidence-based assessment of the system's strengths and weaknesses and its policy-related opportunities and threats in the light of the Lisbon process ("SWOT" analysis).

The national research system is defined in functional terms as an open system comprising actors, institutions and the processes by which they interact to contribute to the production and circulation of scientific, technical and related knowledge, as well as to the mobilisation of resources and articulation of demand for R&D. Thus, the research system also includes research policy actors, together with actors and institutions at the interface with the wider innovation system. The national dimension remains important, but it has to be seen in the broader context of an increasingly open system. The report focuses here on the European context of the national research system. Many of the challenges analysed also reflect important concerns of the European Research Area (ERA). Where interactions with the EU level are relevant in addressing domain challenges they are explicitly included in the system characteristics and trend analysis – insofar as the information is readily available. In addition, the jointly agreed research-related EU Lisbon Strategy goals serve as a key reference for assessing recent trends and policy developments.

This report is based on a synthesis of information from the European Commission's ERAWATCH Research Inventory[1] and other important publicly available information sources as of autumn 2007. In order to enable a proper understanding of the research system, the approach taken is mainly qualitative. Quantitative information and indicators are used, where appropriate, to support the analysis. After an introductory overview of the structure of the national research system and its governance, chapter 2 analyses resource mobilisation for R&D. Chapter 3 looks at knowledge demand. Chapter 4 focuses on knowledge production and chapter 5 deals with knowledge circulation. Each of these four main chapters contains a subsection on relevant recent policies in the domain. The report concludes in chapter 6 with an overall assessment of the strengths and weaknesses of the research system and governance and policy dynamics, opportunities and threats across all four domains in the light of the Lisbon Strategy's goals.

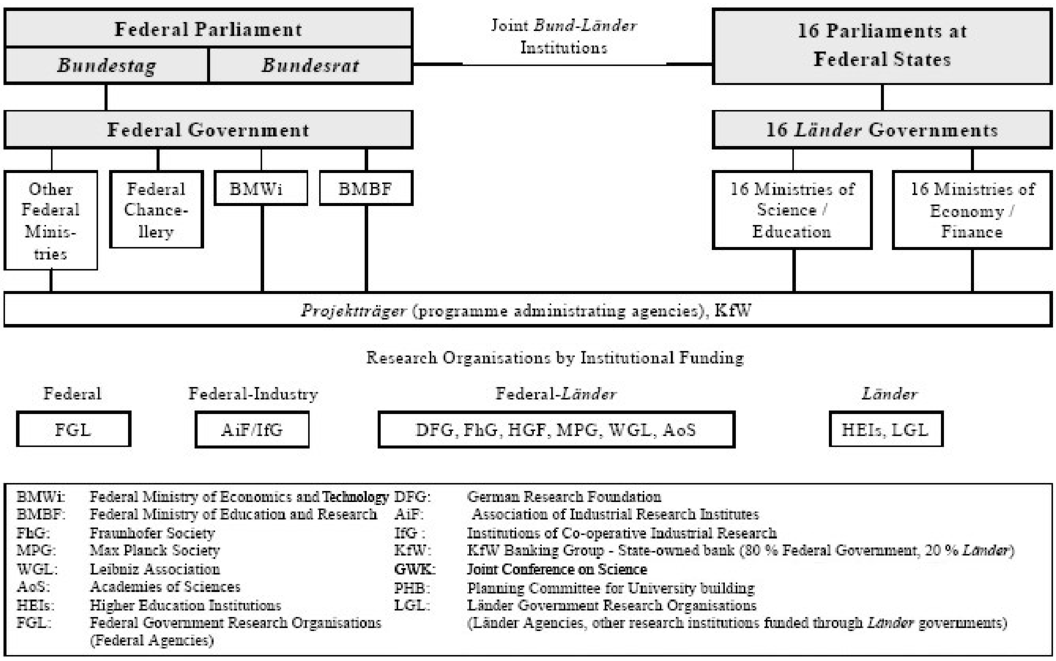
[1] ERAWATCH is a cooperative undertaking between DG Research and DG Joint Research Centre and is implemented by the IPTS. The ERAWATCH Research Inventory is accessible at http://cordis.europa.eu/erawatch/index.cfm?fuseaction=ri.home. Other sources are explicitly referenced.

1.2 Overview of the structure of the national research system and its governance

Measured in terms of R&D expenditure, Germany has the largest research system in the EU. Due to the federal structure of the German political system, political responsibility for R&D policy and funding is shared between the Federal Government and the 16 state (Länder) governments (see figure 2 below). Most importantly, the states have the constitutional right to legislate on education, including universities, and they apply a whole range of programmes in R&D and in innovation policy. Apart from expenditure on universities, however, most public resources for R&D come from the Federal level.

At the Federal level, the BMBF (Federal Ministry of Education and Research) has the main responsibility for research policy. The BMWi (Federal Ministry of Economics and Technology, known until 2005 as BMWA) is responsible for technology policy and even took over some responsibilities for R&D policy from the BMBF in 2005. Its current remit comprises not only SME-oriented indirect measures and energy research, but also aerospace and transport research, business R&D and patent issues. Each sectoral ministry has its own research institute(s). The German Parliament has a permanent Committee on Education, Research and Technology Assessment. At the state level, responsibility is usually shared between the science and education ministry and the economics ministry. Until the end of 2007, the main body for coordination of research policy between federal and state governments has been the Bund-Länder Commission for Educational Planning and Research Promotion (BLK), which is now substituted by the new Joint Science Conference (GWK).

Figure 1: Overview of the governance structure of the German research system



Source: ERAWATCH Research Inventory, http://cordis.europa.eu/erawatch/index.cfm?fuseaction=ri.content&topicID=35&countryCode=DE&parentID=34

Unlike in other countries, there is no strategic policy council to coordinate research and/ or innovation policies. Some aspects of the work of a strategic council for research policy are performed by the German Science Council (Wissenschaftsrat), a joint institution with representatives from both federal and state levels, whose main function is to evaluate and advise on the development of higher education institutions, science and the research sector. In addition, a new “Advisory Council for Innovation and Growth”, which reports directly to the Chancellor, began its work in May 2006. It has 17 members from industry and science and is chaired by the former CEO of Siemens, Heinrich von Pierer.

The Deutsche Forschungsgemeinschaft (German Research Foundation, DFG) is the central funding agency for fundamental research in Germany, complementing the institutional funding for basic research with project-type funding. Most publicly funded R&D programmes are administered and managed by a range of implementation agencies (“Projekttraeger”), which are mostly located in large research centres. The central concern of the German Federation of Industrial Research Associations "Otto von Guericke" (AiF) is the promotion of applied R&D for the benefit of small and medium-sized enterprises.

Private R&D performers are responsible for nearly 70% of the German R&D expenditures. Politically they are often represented by the "*Stifterverband für die deutsche Wissenschaft*" (an association of mainly private, science-funding bodies).
The more than 300 universities traditionally form the backbone of the German public research system. The German Rector's conference (HRK) is the umbrella organisation. In addition, there are four important public non-university research organisations:

1. The MPG (Max Planck Society) currently maintains 80 institutes, research units, and working groups mainly in the field of basic research.
2. The FhG (Fraunhofer-Society) offers scientific and technical expertise on the market for research and development services.
3. The HGF (Helmholtz Association) is Germany's largest scientific research community. It has been commissioned to perform research which contributes substantially to answering the major challenges facing science, society and industry.
4. The WGL (Leibniz Society) is working at the interface of problem-oriented basic research and applied research.

Another relevant block of public research performers consists of Government agencies and institutes performing research, which have organised themselves under the umbrella of "AG Ressortforschung".

Chapter 2. Resource mobilisation

The purpose of this chapter is to analyse and assess how challenges affecting the provision of inputs for research activities are addressed by the national research system: its actors have to ensure and justify that adequate financial and human resources are most appropriately mobilised for the operation of the system. A central issue in this domain is the long time horizon required until the effects of the mobilisation become visible. Increasing system performance in this domain is a focal point of the Lisbon Strategy, guided by the Barcelona objective of a R&D investment of 3% of GDP in the EU as a whole and an appropriate public/private split.

Four different challenges in the domain of resource mobilisation for research can be distinguished which need to be addressed appropriately by the research system and research policies:

- Securing long-term investment in research
- Dealing with uncertain returns and other barriers to private R&D investment
- Providing qualified human resources
- Justifying resource provision for research activities

2.1 Analysis of system characteristics

Germany, as the largest and very research-intensive EU Member State currently spends €56.356 billion per year (2005)[2] on R&D. It contributes significantly to EU resource mobilisation, being responsible for 28% of aggregate EU-27 R&D expenditure. R&D intensity (measured as a percentage of GDP) stood at 2.51% in 2005, which is significantly above the EU average of 1.84%. This share is fairly stable and is roughly similar to that of West Germany in the 1980s before German reunification. The share financed from abroad - at 2.5% (2004) - is relatively minor.

2.1.1 Securing long-term investment in research

Three main partners interact to secure the necessary long-term investment for research and research infrastructures. They are: the federal government, within which the Ministry of Research and Education is the key actor; the regional governments, which are responsible for university funding; and the private sector, which is responsible for private R&D investment. As institutional university research is financed at regional level, the 16 regions (*Länder*) together provide more than half of all public R&D funding. Based on a formal agreement concluded in 1975, the federal and the state levels coordinate joint block funding of the non-university public research system via the BLK and the competitive funding of basic research through the German Research Foundation. The total amount of this joint block funding is about €6 billion (5.8 billion in 2005, the most recent year for which consolidated data are available). This is complemented by project-based R&D funding which is mainly provided at federal level, and which reached €2.5 billion in the 2007 budget. Although BMBF has primary responsibility for coordinating all federal R&D resources, other ministries decide on their own R&D activities independently.
The financing commitments have to be implemented through the budgeting processes at both federal and national level. At the federal level, there is five-year budget planning on a rather aggregate level, while the details are implemented in annual budgets adopted by the Parliament. However, multi-annual resource commitments are possible. In this complicated resource provision structure, in which long-term financial commitments always have to be negotiated, significant increases in public funding are not easy to achieve.

To secure long-term investments, many large research facilities are provided by research institutes that are owned and funded by the state (in particular, the Helmholtz centres). At the federal level, the focus is on facilities for physics. The funding decision for new facilities is usually based on recommendations of the Science Council. The use of the facilities made available by universities is enhanced

[2] If not referenced otherwise, all quantitative indicators are based on Eurostat data sourced April 2007.

by a specific project funding line. The government sector receives 41% (2004) of all publicly financed R&D, while universities receive 45%. Federal block funding for large facilities was €412 million in 2006 (BMBF, 2006a).

Germany takes an active part in all international research organisations providing infrastructures which are financed and operated jointly with partner states. With regard to the financial contribution, the most important organisations are the European Space Agency (ESA), for which Germany provides €573 million (2005) and the European Organization for Nuclear Research - European Laboratory for Particle Physics (CERN). Institutional funding for large international research facilities was nearly €200 million (2006) (BMBF, 2006a); this is supplemented by project funding. Germany is also a member of the ITER consortium for the fusion research reactor. Experts involved in this field estimate that German companies/research organisations received about €900 million from the EU Framework programme (FP6) in 2005. However, no official data on this are available.

Institutionally, therefore, the basic mechanisms for securing long-term investment in research are well established, but making changes is complicated (see also section 2.2.2). For long-term investments in research, government funding plays the most important role. However, the share of public funding in total R&D funding dropped by more than 6% between 1993 and 2003 (ERAWATCH Network, 2006) and, in particular, expenditure by the *Länder* declined in relative terms. Measured as a percentage of GDP, government budget appropriations for R&D - at 0.77% (2005) – are only slightly above the EU 25 average of 0.74%. Enhancing the mobilisation of public resources is therefore regarded as an important challenge for the German research system (BMBF, 2006b, Rammer, 2007).

2.1.2 Dealing with uncertain returns and other barriers to private R&D investment

There are a range of actors and mechanisms in the German research system whose task is to successfully deal with barriers to private R&D investment. Two thirds of R&D is financed by the private sector. More than half of this is directed towards the "R" component, and mostly to applied research. 88% (2005) of private R&D is conducted in firms with more than 500 employees (Stifterverband, 2007). About three quarters of business R&D is conducted by large multinational firms who can more easily handle the risk of R&D investments (Belitz, 2006). Foreign affiliates play an important role in business R&D. However, as data from the German science statistics (Stifterverband, 2006) suggest, they finance their R&D expenditure mainly from resources earned in Germany. The three biggest German-owned R&D investors, which belong to the world top 15, are DaimlerChrysler (€5.65 billion in 2005), Siemens (5.15 billion) and Volkswagen (4.1 billion) (European Commission, 2007).

The conventional funding mechanism for business R&D is intramural and internal funding, favoured by a long-term orientation encouraged by cross-ownership of company shares by other firms and banks. However, this model has been declining in recent years. Historically, other capital market mechanisms, such as venture capital, have played a minor role and for the most part are still used only for the 'new' R&D-intensive sectors, such as biotechnology. Availability of venture capital was adversely affected by the capital market downturn after 2001. Private foundations have so far played only a marginal role. The biggest foundation for R&D is the *VolkswagenStiftung,* which spends up to €100 million per year. Many smaller private foundations are managed through the *Stifterverband für die deutsche Wissenschaft,* which channelled €96 million into research in 2005.

Direct government funding of business expenditures for R&D has been constantly decreasing in relative terms and now accounts for 5.8% (2004). In most sectors it is below 10%, and hence less important for mobilising business R&D resources. The sole exception – albeit a significant one - is Aerospace R&D, which receives about 55% of its funding from government. Public support for industrial R&D mainly takes the form of grants for collaborative research in programmes of the Research Ministry and the Ministry of the Economy. One important institutional arrangement is the joint funding with industry of collective industrial research under the umbrella of the German Federation of Industrial Research Associations "Otto von Guericke" (AiF), which is often underpinned by sector-specific R&D institutions. In some of the *new Länder*, European Structural Funds play an important role in support programmes and infrastructure for business R&D and innovation (ERAWATCH Network, 2007).
Other instruments, such as grants for industrial researchers and specific fiscal incentives for R&D on top of the customary treatment of R&D as a fully tax-deductible expense, were abandoned at the end of the 1980s as their effectiveness was judged to be limited, even though some of these instruments were still used in Eastern Germany in the first transition period.
Indirect public support through the facilitation of venture capital and the provision of guarantees and loans has a long tradition and is mainly managed by the "*Kreditanstalt für Wiederaufbau*" (KfW), which acts as the government's main capital provider for a range of customers, including companies performing R&D (Rammer, 2007).

The performance of the system with regard to private R&D is often viewed as a strength of the German research system (e.g. BMBF, 2006b). In the last decade, funding of R&D by business has continued to increase at a rate roughly equal to the EU average (IPTS, 2007), although it is stagnating recently (Stifterverband, 2007). Privately funded R&D expenditure accounts for 1.67% of GDP, which is far above the EU 27 average of 1.01%. Many German companies are among the top R&D resource providers in their respective sectors (European Commission, 2007). Also the main mode of government support, grant-based competitive funding is assessed as highly effective (BMBF 2007b). Any challenges referred to with regard to business R&D (e.g. Rammer, 2007), in fact tend to be related to the structure of private R&D demand (see section 3).

2.1.3 Providing qualified human resources

Germany is characterised by a well established higher education system, which enjoys a strong reputation in many areas. The so-called "Humboldt model" of combining research and educational activities in universities remains important and has led to a broad research base. This has it made possible to endow large numbers of students with research-oriented qualifications.

However, the Humboldt model has also resulted in a rigid pattern of typical researcher careers, with a high degree of dependence on the supervising professor during the PhD and PostDoc stages, which are the most productive phases. This has increasingly been seen as a bottleneck and a disincentive, representing an obstacle to the recruitment of well qualified young researchers. Policy measures aimed at improving the careers of young researchers have always been controversial. In 2002, the previous government introduced a reform in the career track of post-docs (*Juniorprofessur*) on a voluntary basis to allow earlier independent research and a more predictable career path. However, implementation so far by universities has fallen short of expectations as there have been only about 1000 junior professors, and career prospects after completion of the junior professorship are still uncertain. At the same time, the maximum duration of a series of temporary contracts for researchers was limited to 12 years and restricted to the qualification phase. This created more uncertainty for a group of researchers who had not yet obtained a permanent contract through a professorship. In April 2007 a new law on temporary contracts in science entered into force which makes the application of the time limits more flexible. In addition to these regulations, the widening range of Federal research programmes contains measures which are specifically focused on supporting promising groups of young researchers.

In science and technology related areas, in particular, German universities have been able to attract foreign students and researchers, and exchange programmes are well established. Two federal institutions - the *Deutscher Akademischer Austauschdienst* (DAAD) and the Alexander von Humboldt Foundation - provide a number of support programmes. With the German immigration law finally being adopted in 2004, the legal status of foreign students and researchers became clearer and, even before that, specific measures had been put into place to encourage highly-skilled immigrants.

Assessments of the system's performance in terms of providing researchers are not unanimous and they tend to follow a cyclical pattern (Rammer, 2007). After these concerns reached a peak the end of the 1990s and decreased thereafter, more recent studies have again tended to emphasise the scarcity of suitably qualified people, and the lack of highly skilled young people in particular (when comparing internationally), as a weakness of the system (BMBF, 2006b, 2007a). The main reason is the decline in the numbers of graduates in science and engineering between 1998 and 2003. The comparatively low percentage of women among science graduates is also mentioned.

2.1.4 Justifying resource provision for research activities

The need for Germany to position itself at the forefront of scientific and technological progress in order to preserve future prosperity and competitiveness has always been emphasised in policy documents as a justification for channelling resources into research. Examples include the agreement between the Christian Democratic and Social Democratic parties in 2005 to form a coalition government and the National Reform Programme. For nearly 10 years, the main analyses of the Federal Research Ministry have been presented in the "Report on the technological competitiveness of Germany”. These reports are produced annually and are always the subject of a parliamentary debate. Before 2005, the research-related aspects of the Lisbon Strategy, and in particular the Barcelona 3% objective, did not play a major legitimising role; however, under the new Government this has changed (see 2.2.2).

The enhancement of public understanding of science and humanities is another way to improve the justification of resource provision. One important instrument is the "Year of Science", an awareness raising campaign which focuses each year on a different topic. 2006 was the “Year of Informatics”, 2007 has been the "Year of the Humanities". Each of the Years of Science is evaluated ex post.

The private sector, in particular through industry associations, has also run a number of awareness campaigns promoting S&T studies in schools and among the general public.

The importance attached to the role of research in maintaining competitiveness is only partially reflected in the share of the total government budget that is allocated to public R&D expenditure. At 1.64% (2005) it is still slightly above the EU 25 average of 1.56%, but has declined by comparison with its level of over 2% in the early 1990s. The main explanation for this pattern lies in the competing demands for resources brought about by German reunification. More recently, rising unemployment and also increasing expenditures on interest and debt management were the main drivers of competing demands.

2.2 Analysis of recent changes and policy initiatives

2.2.1 Relevant recent trends

Although the internationalisation of the R&D system as such is not a recent trend, there has been a recent increase in its relevance to the mobilisation of resources. Globalisation is now frequently used as a rationale to legitimise higher public funding of R&D (e.g. BMBF, 2006b). Moreover, in recent years worries about the risk of a brain drain of German researchers to other countries, in particular the US, have been voiced by a range of actors and have been taken up in the media.

The declining trend in the number of S&T graduates has already been mentioned. However, the anticipated rise in the overall number of students has dominated recent debate. With the transition towards a bachelor and master system at German universities, the number of graduates is expected to show a significant rise, at least temporarily, due to accelerated studies and lower drop-out rates.

Lastly, mobilisation of resources for R&D in some of the new Länder cannot rely to the same extent on European Structural Funds for the period 2007-2013 as before, as some parts of Saxony, Saxony-Anhalt and Brandenburg are now phasing-out regions.

2.2.2 Role and expected impact of recent policies

With regard to resource mobilisation objectives, the coalition government, comprising the Christian Democratic and the Social Democratic parties, has given high priority to reaching the target of R&D expenditure reaching 3% of GDP by 2010, emphasising this in the preamble to its coalition agreement of October 2005. It has confirmed this goal in the National Reform Programme, which was drafted immediately after the new government had taken office (Bundesregierung, 2005).

Three recent initiatives form the cornerstone of reinforced *public resource mobilisation*:

1. The "Six Billion Euro Programme for R&D"
2. The Pact for Research and Innovation
3. The Initiative for Excellence for the German University sector

The "Six Billion Euro Programme for R&D" for the period 2006 to 2009 was approved by the Federal government in April 2006, starting with €600 million for 2006 after the adoption of the general budget in June 2006. Besides additional funds for the Initiative for Excellence, it provided the resource base for the implementation of the High-Tech Strategy adopted at the end of August 2006 (BMBF, 2006c, see section 3.2.2 and 4.2.2 for more details). Two thirds of the funds are for the BMBF, which is also the lead manager of the programme. €1.2 billion go to BMWi programmes, and the rest is divided between various other federal ministries. One expected impact is the mobilisation of additional R&D investment from the *Länder* and business. To this end, parts of the additional budget are to be channelled into industry, in particular SMEs. This will be in the form of increasing the budgets of existing collaborative programmes and a new grant-based type of support to public sector institutions that conduct research for SMEs (for details on the latter, see section 5.2.2). While effects of the circulation of knowledge between sectors are to be expected, the effect in terms of additional resource mobilisation remains to be seen.

In the Pact for Research and Innovation agreed in June 2005, the Federal and the state Governments undertook to increase the institutionally funded budget of each of the four main public research organisations and the DFG 2006-2010 by 3% per year. This undertaking has been implemented in the budgets for 2006 and 2007, and the two initiatives together have, after a period of stagnation in real terms, led to related increases in federal public R&D funding. For example, in 2007 the BMBF budget has risen by 6.1%.

The purpose of the “Initiative for Excellence” launched by the Federal and State governments is to strengthen world class universities and university departments (for details see section 4.2.2). Under a formal agreement of July 2005 a total of €1.9 billion is to be provided by 2011, of which 75% will be covered by the Federal Government and 25% by the host state of the successful universities. Initial financial commitments were made at the end of 2006. For some regional governments it will be a difficult task to fully deliver on their financial contributions to the Excellence Initiative. Around one tenth of the resources are earmarked for improving human resource provision by providing €1 million of funding per year for 39 PhD graduate schools selected until October 2007.

All three initiatives were proposed by the previous federal government a number of years ago, but it has not been possible until recently to complete the negotiations between the federal and the regional levels of government. This is a typical characteristic of national public R&D governance, as the multi-level governance model raises issues of both co-ordination and political majority. For instance, it was only thanks to its majority in both chambers of the parliament that the new government was able to launch its “Six billion Euro for R&D” programme.

Even if the Six Billion Euro Programme is fully implemented with additional funds, it will not be enough to achieve the goal of 1% publicly funded R&D intensity in 2010, as the additional six billion are spread over a period of four years, whereas in fact an additional public investment of six billion *each year* would be needed to achieve the public part of the Lisbon objective (BMBF, 2006b). This has recently become all the more relevant against the background of increasing economic growth rates.

Further new initiatives to improve *private-sector R&D resource mobilisation* were implemented recently. One set of measures addresses new technology-based companies. The new "*High Tech Gründerfonds*” with a budget of €260 million over five years, is one of the results of the "partner for innovation" initiative which was chaired by the former chancellor and brought together a range of eminent industrialists, politicians and scientists between 2004 and 2006. It was launched in August 2005 and is operated by a newly created independent organisation. Another set of measures supports R&D-intensive spin-offs from universities (the EXIST seed programme). A pilot scheme in East Germany has been in huge demand and was extended to the whole country in 2006.

With regard to policies on further *human resource mobilisation* and university infrastructure provision, the funding trends at *Länder* level – where the political responsibility lies - seem to run counter to recent federal budget increases (Rammer, 2007). The powers of the regions concerning universities have actually been strengthened as a consequence of the recent huge effort to reform German federalism. This process was concluded in mid-2006 after four years of preparation to achieve a sharper division of tasks. Nevertheless, given the growing number of students, a third agreement between the federal and the regional level concerning the long-term funding of the higher education sector (*Hochschulpakt 2020*) has been concluded mid 2007 after tough negotiations. Here, a new burden-sharing model for research and education at universities has emerged. It consists of compensation measures between regions for the costs of students, burden sharing for large infrastructure investments and additional federal funds for the overheads of DFG projects, to facilitate the transition to full-cost budgeting by universities. In fact, the agreement calls into question the very rationale of the reform of federalism in relation to education.

2.3 Assessment of resource mobilisation

The main strengths and weaknesses of the German research system in terms of resource mobilisation for R&D can be summarised as follows:

STRENGTHS:	WEAKNESSES:
- Stable mechanisms in place to ensure long-term research funding - Functioning mechanisms for the provision of a strong human resource base for R&D - The two-thirds share of private R&D funding already meets Lisbon objectives	- Necessary multi-level negotiations for increases in long-term public funding are time-consuming and require political majorities, which are often difficult to achieve

The main opportunities and threats for resource mobilisation in Germany arising from recent policy responses and in the light of the Lisbon Strategy can be summarised as follows:

OPPORTUNITIES:	THREATS:
- Increased volume and greater political focus on public resource mobilisation through the federal "Six billion Euro programme"	- Public resource mobilisation, in particular at the Länder level, is insufficient to meet the Lisbon target - Private resource mobilisation might not respond to increased incentives to the extent anticipated

Chapter 3. Knowledge demand

The purpose of this chapter is to analyse and assess how knowledge demand contributes to the national research system's performance. It is concerned with the mechanisms used to determine the most appropriate use of, and targets for, resource inputs. Main challenges in this domain relate to governance problems stemming from specific features of knowledge and the need for priority setting. These include:

- Identifying the drivers of knowledge demand
- Co-ordinating and channelling knowledge demands
- Monitoring and evaluating demand fulfilment

Responses to these challenges are of key importance for the more effective and efficient public expenditure on R&D aimed at in the Lisbon Strategy Integrated Guideline 7.

3.1 Analysis of system characteristics

The sectoral structure of the German economy reflects the economic importance of technology-driven competitive advantage based on the prominent role of early science-based industries such as chemicals, machine tools, electrical equipment and cars, and has led to a high demand for R&D in comparison with other countries. Private R&D demand in particular is driven by medium-high-tech manufacturing sectors. The latter perform 65.6% (2003) of manufacturing BERD, which is far higher than the EU average. Correspondingly, at 26.6%, the share of high-tech manufacturing in BERD is much lower than the EU average. This is also reflected in BERD specialisation compared with EU 15, which shows a high (and rising) level of specialisation in motor vehicles, chemicals and fabricated metals (ERAWATCH Network, 2006). The share of BERD performed in the service sector - which was 8.1% in 2003 - is among the lowest in the EU. This may be due in part to limited outsourcing from the manufacturing sector. Demand for service-related R&D has not increased strongly as it has done in other countries; instead it has been characterised by a stable share of BERD over the last five years.

More than half of public demand as expressed in government appropriations (GBAORD) is non-targeted, while 43.1% (2005) is directed towards specific socio-economic objectives. Specialisation of government-funded R&D compared to the EU 15 is more than 20% greater on social issues and the environment, and is more than 20% lower in human health, defence and agriculture (ERAWATCH Network, 2006).

3.1.1 Identifying the drivers of knowledge demand

There is an established set of mechanisms for identifying knowledge demand drivers. The conventional policy mechanisms were technology oriented. Technology forecasting, in the form of Delphi studies, has played a supporting role, particularly in the second half of the 1990s. The forecasting process "Futur" - The German Research Dialogue", which was operated between 2001 and 2005, was an attempt to bring about a more inclusive agenda-setting process (see also IPTS, 2006). Despite a positive evaluation by an international expert commission (Cuhls and Georghiou, 2004), the effects of Futur are unclear and the results have not been directly implemented in national R&D policy.
In addition, the German Parliament runs the "Office of Technology Assessment" (TAB), an advisory body attached to the Bundestag. It commissions studies to

assess the impact of various technological developments and problems in the field of technology.
In recent years, both the Ministry, via its analyses on innovation and technology, and Parliament, via TAB, have taken greater account of the demand side.
Strategy papers or plans as tools to identify and articulate demand for knowledge, based on corresponding analyses, play a less prominent role than in other countries. In this respect, the recent High-Tech Strategy is somewhat of an exception (see section 3.2.2 for details).

The DFG is the main institution articulating new demands for basic research. One recent example was the request in October 2006 for changes in the stem cell law. While it is true that ethical limits play an important role in shaping societal demands in fields such as biotechnology (stem cell law, resistance to the application of green biotechnology) and nuclear technology (nuclear power phase-out), this argument cannot be generalised and it has not necessarily led to significant decreases in R&D in those fields.

However, as a result of the business culture and the stable sectoral structure in Germany, e.g. with the automobile sector even accounting for an increasing share in private knowledge demand, it is hard to find users for new knowledge that goes beyond incremental improvements. Also consumers tend to value solidity over novelty, with the result that Germany rarely takes on a conventional lead market role for radical innovations derived from scientific breakthroughs in new fields of knowledge.

The increased internationalisation of R&D is raising the importance of external drivers of knowledge demand. German multinationals, as well as many medium-sized enterprises, are outward-looking, and studies show that Germany is a very attractive location for private R&D activities in Europe (e.g. Belitz, 2006). At government level, however, there are hardly any measures in place to seek out potential external demand. The main mechanisms for demand articulation in the policy process remain inward looking.
Business R&D decisions are taken predominantly by firms based in Germany. The three biggest sectors in terms of private R&D funding are motor vehicles, with more than €10 billion (32% of business R&D 2001), chemicals (with more than €5 billion) and machinery and equipment (around 10% of business R&D). Those R&D demands which are not met by in-house R&D capacities are directly articulated by funding R&D in the higher education and government sector, which receives 3-4% of total business R&D funding. Indirectly, and more importantly, demand is articulated through intermediaries and participation in the political process. One important intermediary in this respect is the *Stifterverband für die deutsche Wissenschaft*, which participates in political debates, manages its own small support programmes with funding of around €20 million a year and co-operates institutionally with the German Research Foundation and the Max-Planck-Society to help articulate business R&D demands into science. One example is the temporary funding of new university chairs (*Stiftungsprofessuren*; for another example, see section 5.2.2).

3.1.2 Co-ordinating and channelling knowledge demands

Policy acts as a conduit for society's demands through the launching of research programmes and through its involvement in steering non-university public research institutions or, even more directly, by running designated governmental research institutes. German research and technology policies have preserved a mission-oriented element in the way they set priorities with regard to identified knowledge demands. Thematically oriented public R&D funding, as the main instrument, is dealt with at the federal level. The BMBF plays the main role. The basic approach, as expressed in dedicated research programmes, is technology-oriented. Areas on which attention is focused include ICTs, life sciences, microsystems, nanotechnology, optical technologies, materials and production technologies, energy and sustainable development. Other ministries also have sectoral research programmes and institutes. These include the ministry of the economy and technology, the ministry of the environment, the ministry of defence, the ministry of transport, building and urban affairs and the ministry of food, agriculture and consumer protection. Taken together, about a quarter of government appropriations are primarily directed towards economic objectives (energy, agriculture, industry, space), while around 15% also include a social or environmental focus (land-use, environment, health). The channelling of demand over time has remained fairly stable, the exception being a significant decrease in the share of defence-related funding over the last ten years, down to 5.8% in 2005.

Coordination of the various targeted R&D activities in the different ministries is limited. There are formal procedures in place under the overall responsibility of BMBF, but their effectiveness beyond simple information exchange appears to be limited. There is no direct co-ordination of priority setting between the Federal and regional levels, although the regional level often tries to complement the federal initiatives (ERAWATCH Network, 2007). With the new High-Tech Strategy, for the first time a more integrative approach has been chosen at the federal level (for details see section 3.2.2). Institutional R&D funding is largely decoupled from political priority setting. The only exception is the HGF, where funding has been reorganised along the lines of broadly defined thematic programmes. In some areas, such as defence and, to some extent, health, public procurement is used as an instrument to channel the demand for new knowledge.

Priority setting in general is mainly an administrative process organised by the ministry, based on consultation of experts, with economic actors being included in the process to varying degrees. The channelling of private demand signals is well established in classical areas of national R&D priority setting, mainly technology and/or sector-based topics such as production technologies, optical technologies and so on. Collaborative research in thematic research programmes seems to work as an effective tool in cases where the scientific and economic drivers of knowledge demand coincide, as in the case of life sciences or nanotechnologies. Here, the responsiveness of policy actors to demand from the private sector is very high. The same holds for other instruments aimed at encouraging private R&D. For example, the new "Research Grant" to encourage more applied research by public R&D institutions (see section 5.2.2) has been proposed by the Federation of German Industries and channelled via the "partners for innovation" initiative.

Project-based funding within research programmes, as the dominant method of implementing public R&D priorities, allows a degree of flexibility and the inclusion of new focal points. Some of the increase in nanotechnology funding initially took place within existing schemes. The definition and approval of new research programmes is a time-consuming process and does not occur often. Changes, such as an increased articulation of demand for R&D with relevance for environmental protection or the rise of nanotechnologies on the research policy agenda, take place relatively slowly.

The international dimension, for example the EU with its Framework Programme, increasingly acts as an additional mechanism to channel the demand for knowledge. Until now, European activities have had only a minor direct effect on national priority setting. Care is taken to ensure that national priorities are sufficiently reflected in European programmes (BMBF, 2006d), and FP and national main thematic areas do generally coincide. German actors are also present in a range of ERANETS with a view to co-operation between national research programmes. However, the indirect impact of European priorities on research actors should not be underestimated. One indication is that, by 2005, FP 6 funding for German universities had reached more than 40% of the amount obtained by national direct project funding 2002-2004 (DFG, 2006).
Beyond the EU level, the bilateral relationships in Europe between Germany and France have always received particular attention. There are regular meetings and efforts to co-operate on European research policy, as well as to increase bilateral co-operation between similar institutions in selected fields. The main themes addressed in the latest joint paper by the two governments in March 2006 are transport, genomics, nanotechnologies, cancer research and environmental sustainability (Auswärtiges Amt and Ministère des Affaires étrangères, 2006).

3.1.3 Monitoring and evaluating demand fulfilment

Since the mid-1990s, evaluation has become a core feature of the monitoring of new R&D policy initiatives (for details, see also Kuhlmann, 2003). As a rule, every new research programme is evaluated ex post by independent research institutes on behalf of research policy administrators, although the results are not always published. The main focus has been on impact analysis, but with the rise of co-operation and networking programmes process- and actor-oriented evaluations have also gained some ground. Competitive project-based funding plays an important role in the channelling of knowledge demand, and here every project is evaluated ex ante. Germany has significantly stepped up the use and methodological accuracy of evaluation throughout the life cycle of R&D policy measures. It is not always clear, however, to what extent the results of the evaluations have been considered before new R&D policy measures or programmes are launched. A positive example in this regard is the strategic evaluation of the "joint industrial research" mechanisms (Rammer, 2007).

In addition, since 1999 "system evaluations" of the German Research Foundation (DFG), the Max Planck Society (MPG), the Fraunhofer Society (FhG), the institutions of the "Science Community GW Leibniz (WGL)" and the national science centres in the "Helmholtz Society" (HGF) have been completed; this process was organised by the Science Council and frequently supported by international commissions (e.g. Wissenschaftsrat, 2001, for an overview, see Kuhlmann, 2003). The most recent one completes the evaluation cycle by evaluating the government research institutions of the federal sectoral ministries ("Ressortforschung") with respect to the relevance and quality of their R&D activities. The results on the main 13 institutions were published in April 2007, an evaluation of the further 39 institutions will follow by 2009. The work of the majority of these agencies is assessed by the German Science Council as being of high scientific quality, in particular in the field of applied research, concentrating on process development and method testing in the natural sciences,

engineering, and social sciences. Some institutions, however, fall short in terms of both meeting the expectations of public administrators, and satisfying the quality standards of scientific communities (Wissenschaftsrat, 2007; on the policy implications see also section 4.2.2).
The results of such system evaluations have usually been widely discussed and have resulted in adjustments. For example, the large-scale research centres of the Helmholtz Association (HGF) have been found not to adequately fit the needs of the German R&D system, as they have performed R&D without a clear strategic focus (Wissenschaftsrat, 2001). Thus, their governance has been changed from centre-based funding into funding via thematic programmes, which also include joint R&D projects with business. The HGF programmes themselves are evaluated on a regular basis.

Relevant non-government actors which contribute to monitoring and evaluation are the German Research Foundation, and the *Stifterverband* and the *Centrum fuer Hochschulentwicklung* (for further details see section 4.1.1 and 4.1.2).

German practice in the area of evaluating the performance of research and research institutions has been assessed as strong. Little effort has been made, however, to coordinate and systematize evaluation practices (Kuhlmann, 2003).

3.2 Analysis of recent changes and policies

3.2.1 Relevant recent trends

There are few relevant recent changes that are not policy related. Unlike in other countries, demand drivers in the private sector have remained fairly stable and linked to the established sectors. Most of the recent growth is concentrated in the established sector of motor vehicles, as well as chemicals and computer-related services. The increasing orientation of private R&D demand towards the automotive sector is perceived as a weakness in the light of the expected growth in demand in other areas of the world and possible future relocations of production (BMBF, 2006b). A further risk related to demand dynamics is seen in R&D-intensive sectors, where the number of firms is shrinking; and in certain fields such as ICT, electronics and media, imports of R&D-intensive inputs are rising (BMBF, 2006b).

3.2.2 Role and expected impact of recent policies

The most notable new policy initiative with implications for R&D demand articulation is the federal government's High-Tech Strategy, launched in August 2006 (BMBF, 2006c). The strategy combines continuity with some new elements in the strategic approach to public R&D demand articulation. There is continuity in the strengthened approach based on technology areas characterising most of the 17 targeted "innovation fields" and the reliance on competitive project funding as the main instrument. Twelve billion of the €14.6 billion earmarked for the period 2006 to 2009 are for the targeted thematic fields; the rest is for cross-cutting measures (on the latter, see sections 4.2.2 and 5.2.2). The innovation fields are mostly areas in which Germany has traditionally been strong, such as materials sciences, production technologies or transport technologies. More than half of the resources are for three areas: space, energy and ICT technologies.
However, with more holistic approaches in areas such as the health system, security technologies and the service sector, some areas are presented which have not

previously been included in the classic portfolio of R&D policy. These new elements reflect the demand-oriented lead market concept and explicit SWOT analyses, which include this dimension for each field. Moreover, each field's specific strategy has to include an improvement of the framework conditions and an agreement on joint and coherent strategies of science, business and policy. Furthermore, the strategy contains a list of planned implementation measures, one aspect of which is a stronger support role for public procurement in the articulation of knowledge demand. Examples of thematic measures already implemented are the new ICT 2020 research programme, the NanoInitiative 2010 or the new security research programme of January 2007.
While this approach is supposed to bolster the (potential) strong fields of the German innovation system, it may not be the most appropriate way to respond to weak demand signals. Knowledge-intensive services are included as one of the 17 areas, but receive a negligible share of overall funding. The particular aim of the High-Tech strategy is to improve the coordination between R&D activities by the federal-level ministries involved in R&D policy making. In this regard, it represents real progress. It remains to be seen if and how implementing this strategy will ensure the achievement of this objective.
A short chapter is devoted to the European dimension, acknowledging the increasing importance of the FP for Germany, but then focuses mainly on how Germany intends to shape European research policy to achieve the goals of the strategy.

A change in governance with regard to monitoring of demand fulfilment is the setting up of the new BMBF high level advisory group "*Forschungsunion Wirtschaft – Wissenschaft*" (Research Union Economy – Science), jointly chaired by the presidents of the Fraunhofer Society and the *Stifterverband fuer die deutsche Wissenschaft*. The main focus of the work is monitoring the implementation of the High-Tech Strategy, in particular with regard to cross-cutting initiatives, but also with recommendations for the innovation fields. The effects of this formalisation of existing ad hoc mechanisms for consulting relevant stakeholders remain to be seen.

3.3 Assessment of knowledge demand

The main strengths and weaknesses of the German research system in terms of knowledge demand can be summarised as follows:

STRENGTHS:	WEAKNESSES:
- Demand signals from classical industries well addressed by policies - Strong R&D programme basis and well established evaluation mechanisms enable a flexible response to changes in demand	- Demand signals outside the classical technologies/sectors or international demand signals not well addressed

The main opportunities and threats for knowledge demand in Germany arising from recent policy responses and in the light of the Lisbon Strategy can be summarised as follows:

OPPORTUNITIES:	THREATS:
- More effective knowledge demand through better coordination between federal actors and more holistic approaches via the High-Tech Strategy	

Chapter 4. Knowledge production

The purpose of this chapter is to analyse and assess how the research system fulfils its fundamental role of creating and developing excellent and useful scientific and technological knowledge. Any response to knowledge demand has to balance two main challenges:

- On the one hand, ensuring knowledge quality and excellence is the basis of scientific and technological advances. It requires considerable prior knowledge accumulation and specialisation as well as openness to new scientific opportunities, which often emerge at the frontiers of scientific disciplines. Due to the expertise required, quality assurance processes are here mainly the responsibility of scientific actors, but may be subject to corresponding institutional rigidities.
- On the other hand, there is considerable interest in producing new knowledge which is useful for economic and other problem solving purposes. Spillovers which are non-appropriable by economic producers as well as the lack of possibilities and incentives for scientific actors to link to societal demands lead to an exploitability challenge.

Both challenges are addressed in the research-related Lisbon Strategy Integrated Guideline.

4.1 Analysis of system characteristics

4.1.1 Ensuring quality and excellence of knowledge production

The German capacity for the production of scientific knowledge is grounded in a well established university system and a large and unique non-university research system, based on four pillars with different missions. These are the MPG, HGF, WGL and FhG (see section 1.2). The highly differentiated structure of the German research system and its patterns of knowledge creation have proven to be highly durable over the long term (Grupp, 2004).

Scientific research in Germany has a clear focus on the natural sciences and engineering, which account for about half of the research activities in universities and three quarters of those in public research organisations. According to publication data for 2003, the largest proportion of publications is in clinical medicine, accounting for nearly a quarter of the publications in Germany. This field is followed by physics and chemistry, both with shares well above 10% (ERAWATCH Network, 2006). Engineering, coming fifth after biology/biochemistry, accounts for only about 5% of publications, but this small share is mainly due to the inward-looking orientation of German engineering, which leads to under-representation in the international SCI database, and the lesser relevance of scientific publications in this field (Schmoch, 2006). When measured in terms of citations, the patterns are similar, only biology/biochemistry and molecular biology have increased their shares, while the share of engineering has decreased. In relation to the EU 15, Germany shows a clear scientific specialisation in physics, material sciences and, albeit to a decreasing extent, chemistry (ERAWATCH Network, 2006).

The emergence of centres of excellence in basic research has traditionally been left to the research actors themselves, supported by funding from the DFG. This is beginning to change with the recent start-up of the "Initiative for Excellence", which targets top universities (for further details see section 4.2.2). With regard to political support for targeted research, competence centres and competence networks in designated thematic areas and/or regions have already been growing in importance since the end of the 1990s. Starting with major initiatives in biotechnology, the sector-based competence centre and network approach has been widened by the BMBF into other areas such as nanotechnology, optical technologies and medical technologies. These initiatives have often taken the form of contests and have led to the re-structuring of thematic co-operation and co-ordination in a bottom-up way, whereas specific financial input has been comparatively marginal.

Quality and excellence in academic research are fostered by a publicly funded independent institution, the German Research Foundation (DFG). The DFG grants more than €400 million per year for non-oriented basic research on a competitive basis according to scientific excellence and quality criteria based on peer review. In addition, the DFG uses a number of instruments to strengthen the scientific quality of the university system. These range from graduate schools and innovation colleges to awards for outstanding research achievements. In 2005, the DFG set-up a specific institute for evaluation and quality assurance *(Institut für Forschungsinformation und Qualitätssicherung)*. Another institution which monitors the quality and excellence of the public research system is the German Science Council, with its regular evaluations and recommendations (see below). Rankings of the research quality of universities as an additional quality control mechanism are a fairly recent phenomenon which has been particularly fostered by a private not-for-profit organisation, the Centre for Higher Education Development (Centrum fuer Hochschulentwicklung, CHE) of the Bertelsmann foundation and the foundation of the university rectors' conference (see, for example, Berghoff et al., 2006). However, every three years the DFG also publishes a university ranking based on the support received (e.g. DFG, 2006).
Beyond this, each pillar of the public research system has developed its own quality criteria. The MPG uses scientific excellence as its main criterion and the FhG uses contracts from the private sector. For the HGF and WGL, a number of additional criteria can be mentioned, such as the provision of a large state-of-the-art research infrastructure (for the HGF) or the contribution to evidence-based policymaking (for some WGL institutes).
Hardly any information is available on knowledge quality assurance in the private sector; however, provision of qualified human resources is an important element (section 2.1.3).

The German research system has a good reputation for producing knowledge and the capacity to adapt to progress within established scientific fields or to combine them to create new knowledge. The openness to new opportunities is seen to be more problematic when these arise at the fringes of existing fields. There is a long tradition of programme-based government support for research in new high-tech fields. The stimulation and establishment of long-term multi-disciplinary and interdisciplinary research as a way of ensuring the openness of the knowledge production system to new opportunities has been a key objective in most competitive R&D programmes launched by the BMBF and other ministries. However, the strict separation of scientific disciplines in universities, as well as in the non-university research system, has prevented this objective from being achieved on a large scale. On the contrary, the recent focus on scientific publications as a core quality criterion for all elements of the public research system, e.g. in the evaluations of the Science Council, has further reinforced discipline-based research strategies, as it is much easier to situate publications within the context of existing disciplines.

The German research system has demonstrated a strong capacity for producing scientific and, particularly, technological knowledge. This is indicated by data on publications and patents (on the latter, see chapter 4.1.2), as well as a range of system evaluations conducted during the last decade. Germany's knowledge output is significantly above the EU average, as indicated, for instance, by the fact that there are around 800 scientific publications in international journals per million inhabitants (2004) compared with an EU 25 average of 661. However, it is still lower than in many of the other leading European countries, and the average growth rate between 2001 and 2004 was below the EU average. If measured in citations instead of publications, however, Germany still belongs to the leading group of countries with performances close to those of the US and the UK (Schmoch, 2006).

System evaluations of the main research institutions (see section 3.3) confirmed a generally sound and appropriate division of labour, but an inadequate culture of exchange and cooperation and insufficient strategic planning and programming. Following the findings of the evaluations, some changes in governance and priority setting have resulted. However, a main target of criticism, the so-called *'Versäulung'* - the lack of cooperation between the different elements of the public research system and its negative impact on the openness towards new opportunities – persists (see e.g. Heinze and Kuhlmann, 2007). One further response has been the Pact for Research and Innovation agreed in June 2005 in relation to public research organisations (see section 4.2.2).

4.1.2 Ensuring exploitability of knowledge

Ensuring exploitability of knowledge for economic and other societal uses has always been an important feature of the German research system. Patent law and other intellectual property rights institutions have been well established for a long time. Also the large proportion of private R&D indicates that knowledge production is highly market-oriented.

The technical universities, which are internationally renowned (e.g. RWTH Aachen and TU Munich) and which collaborate extensively with business, play a key role in matching knowledge production with economic specialisation. The four main economic sectors - machinery, electronic equipment, chemicals and motor vehicles - are also the four most important fields of technological knowledge production, together accounting for half of all German EPO patent applications. Pharmaceuticals and office equipment follow some considerable way behind. Patent specialisation relative to EU 15 confirms a high level of specialisation in motor vehicles and, to a lesser extent, machinery. Other fields of specialisation are fabricated metals and electrical equipment (ERAWATCH Network, 2006). This specialisation in medium-high rather than in high-tech sectors also manifests itself in the specialisation of business R&D. In general, there is a rather good fit between BERD and value added specialisation. One notable exception is electrical engineering which has lost some of is relative importance in business R&D due to larger increases in automobile R&D and larger increases in these sectors in other EU countries.

Economic exploitability is used as the de facto quality criterion for a number of public R&D support measures, mainly the pre-competitive programmes of BMBF and BMWi. One element covers the design of programmes and projects, to involve the main future users, such as industry, both in the setting up and in the implementation of the programmes. The quality of the proposals for the project-funded research by the BMBF is evaluated ex ante by expert panels, which often include researchers and representatives from industry associations. In general, all publicly funded projects have to develop an implementation plan as a part of their project proposal, describing how the potential results of the projects will be exploited. The organisation responsible for project management evaluates the achievement of these plans five years after the project is completed. Another element is the presentation of the results in a user-friendly way. Specific monitoring processes are often put in place to disseminate the results of the projects during the life-cycle of a programme. In addition, the results of all federal pre-competitive R&D projects are centrally accessible via a database (TIB Hanover).
The increasing focus on thematic and regional clusters and networking approaches in German R&D policy can be seen as a way to further improve the exploitability of research. Since the end of the 1990s, a cluster-based approach has been chosen, for example by the BMBF, to foster knowledge-based development of the East German *Länder* under the umbrella of the "entrepreneurial regions" initiative. One example is the "centres for innovation competency" programme, which supports research centres that meet international standards and gear their basic research towards future high technology markets.

While the responsiveness to the demands of economic sectors is often high, in cross-cutting, policy-related fields it tends to be more limited; this is because the public research system is defined along rigid disciplinary lines, which makes it hard to respond when there is no clear-cut sector and/or technology to which the research can be attributed. Examples are research on sustainability issues, public health or mobility (beyond cars). In such areas, specific research institutes - often rather small ones - have emerged to fill this gap.

The main incentive for academic researchers to link up with economic and policy demands (besides future career prospects in the private sector) is the acquisition of additional funding. A number of Länder have started to use additionally acquired funds as one criterion for the distribution of institutional funding of universities. Experience in the private sector is also a main criterion for becoming a professor at one of the universities of applied science. For other university careers, however, academic quality criteria often dominate. Therefore, the exploitability of knowledge for policy-making and other societal purposes is additionally ensured by setting up specific institutes for evidence-based policy support. The institutes of the WGL, in particular, play an important role in providing evidence and science-based support for policy making. However, the institutes of the HGF are also involved in this field (e.g. on nuclear radiation issues).

Both the indicators and the existing system assessments provide evidence of the high performance of the German system with regard to exploitability of knowledge. With 312 EPO patent applications per million inhabitants (2003), Germany's patent output has doubled over the last ten years and is nearly three times the EU-27 average of 128. A particular strength of the German system is the production of knowledge for established economic sectors, and corresponding incremental innovations which are highly dependent on knowledge accumulation and integration (e.g. Huebner and Nill, 2001; the feature is also highlighted in several of the annual reports on the technological competitiveness of Germany). Moreover, the strategic system evaluation of the "joint industrial research" mechanisms of the BMWi (Blum et al., 2001) generally confirmed the good system response. It pointed to a number of areas for improvement with regard to programme overlaps and more direct targeting of underlying market failures; these improvements have subsequently been implemented in the redesign of the programmes (Rammer, 2007).

4.2 Analysis of recent changes and policy initiatives

Enhancing knowledge quality and exploitability has always been a goal of Federal research policy. The focus on research excellence has been given greater prominence recently. This can be seen in the “Guidelines of Research Policy” (BMBF, 2006d) published in February 2006 under the title “Excellence in education and research – more growth through innovation”; these emphasise Germany's role as a research location and are aimed at achieving an efficient, world-class science system as well as unique profiles of Institutions of higher education and research institutions. The German National Reform Programme also explicitly mentions the increase of research quality as the second goal in the R&D-related section (Bundesregierung, 2005).
The goal of strengthening exploitability of knowledge through enhanced science-industry co-operation is strongly underlined in the National Reform programme and the High-Tech Strategy (BMBF, 2006c), with greater emphasis on clusters as a relatively new element, and it is also reflected in the new "Research Union Economy – Science" (see section 3.2.2).

Arguably the most important recent policy initiative in this field is the “Initiative for Excellence” agreed in July 2005 by the Federal and state governments, which is currently being implemented in several steps by the DFG and the Science Council. The main aim is to support cutting-edge research at universities to create "beacons of science" with international visibility. A total of €1.9 billion will be available until 2011 for increasing the knowledge production performance of top universities and will be awarded via three lines of competitive funding: excellence clusters, graduate schools and future concepts.
The main part is the funding of "Future concepts for top-class research at universities". This programme aims to further strengthen the research profile of up to ten selected universities which will receive on average €21 million per year. As a prerequisite, an institution of higher education must develop a convincing overall strategy to become a globally recognised "beacon of science" and also have succeeded in getting awarded at least one internationally renowned scientific centre of excellence and one postgraduate school. The general philosophy is to concentrate activities on a limited number of fields rather than spread it thinly across many fields. In a first round, the concepts proposed by the University of Munich, the Technical University of Munich and the University of Karlsruhe were selected in a two-stage procedure in October 2006. The latter includes an ambitious plan for a "Karlsruhe Institute of Technology" in collaboration between the University and the Forschungszentrum Karlsruhe, a large public research institute of the Helmholtz Society, which partly tries to overcome the "Versaeulung" ("pillarisation") of the

research institutions. In the second round, concept of six further universities were selected.
Co-operation between universities and non-university research institutions is also the aim of the call for proposals targeted at "clusters of excellence". Research at universities and science organisations is due to be strengthened in the long term through the competitive funding of outstanding centres in specific interdisciplinary fields of research. In two rounds, 37 clusters of excellence have been selected which each will receive around €6.5 million per year.
It is expected that the enhanced priority setting will lead in the long run to more specialised and excellent universities which also have an increased impact on an international scale. Another example (beyond the Karlsruhe Institute of Technology) pointing in this direction is the recently presented "Juelich Aachen Research Alliance" between the Technical University of Aachen and the Juelich Helmholtz Research Centre. The development of the Excellence Initiative has also highlighted the drawbacks of the necessary, but complicated, negotiations between a variety of partners at Federal and state levels, including the scientific stakeholders such as the DFG and the Science Council. The original idea, which for the first time focused strongly on the development of university-wide research strategies, underwent considerable changes during the negotiations. The final outcome, with the split of the resources into three lines, reflects a complicated consensus which might achieve the political objectives to a limited extent only.

Enhancing knowledge quality and the exploitability of public research is one aim of the Pact for Research and Innovation agreed in June 2005 (see also section 2.2.2). In exchange for the government's commitment to increases in funding, public research organisations have made commitments to increase the quality and performance of their R&D activities, by e.g.:

- Benchmarking strengths and weaknesses with regard to excellence,
- Exploring new research fields including risky and non-conventional research, and
- Strengthening clusters and co-operation with industry.

The last item has been chosen as a focus for activities in 2007. The institutions have agreed to deliver annual progress reports which will be publicly available.
The DFG has undertaken to place an increased emphasis on promising projects and research fields with high scientific risks, to strengthen profile development at universities and to support networks between universities and research institutions. It was also given the explicit task to support moves to bring about a European research support system.
It remains to be seen how these objectives will be achieved and whether this approach will significantly enhance the excellence and exploitability of the outputs of these institutions.

The combination of excellence and exploitability of knowledge is also the aim of research-based cluster initiatives between science and industry which are collected into a cluster strategy as part of the German High-Tech Strategy (BMBF, 2006c). Thematic cluster approaches as a tool to implement the thematic field strategies (see section 3.2.2) will be reinforced. For research-based regional clusters in the new *Länder*, the most recent instrument is the "*Innoprofile*" initiative which was launched in 2005. It has a budget of €150 million for the period up to 2012 and its aim is to support R&D projects by young research groups at scientific institutions making use of the region's industrial and scientific profile in terms of specialisation and economic focus. Furthermore, a new cluster initiative was launched by the Federal Ministry of

Education and Research in August 2007. The competition is open to all scientific and technological fields in order to single out Germany's top cutting-edge clusters for awards and contribution to funding. This shall enable these clusters to boost their profile, eliminate impediments to their strategic development and grow into internationally attractive centres. It is hoped that this will have a mobilising effect comparable to that of the Initiative for Excellence. Also in the non-technology specific research support for SME, new cluster approaches will be implemented which will integrate the whole innovation chain, involving basic research possibly supported via the DFG and the use of the AiF support structures for collaborative industrial research.
Another new instrument implemented in early 2007, which is targeted at the exploitability challenge but which might as its main effect improve the circulation of knowledge between sectors, is the new "Research Grant" (*Forschungsprämie),* which supports those public sector research institutions conducting research for SMEs (for details, see section 5.2.2).

Finally, as with previous system evaluations, the recent evaluation of government research institutions by the German Science Council (see also section 3.1.3) can be expected to have a significant parallel impact on governance as a way to also improve the quality and political exploitability of their knowledge production. The recommendations cover the status and management of R&D activities within these institutions, the institutional framework, especially as far as the management of financial and human resources is concerned, and the coordination between agencies and ministries (Wissenschaftsrat, 2007). Some adjustments have already been made during the evaluation process, e.g. the introduction of research programmes by the Ministry of Food, Agriculture and Consumer Protection. The German Government published "Guidelines for a modern government research" as additional response end of January 2007. A follow-up policy document on the topic later this year was announced by the Federal research minister.

4.3 Assessment of knowledge production

The main strengths and weaknesses of the German research system in terms of knowledge production can be summarised as follows:

STRENGTHS:	WEAKNESSES:
- Mechanisms in place to enhance scientific excellence of public research through DFG and Science Council - Strong focus on research closely linked to the economy's strengths	- The rigidity of the public research system, which is strongly geared towards traditional scientific disciplines, makes it difficult to adapt to new cross-cutting opportunities

The main opportunities and threats for knowledge production in Germany arising from recent policy responses and in the light of the Lisbon Strategy can be summarised as follows:

OPPORTUNITIES:	THREATS
- Improved excellence and increased international attractiveness of public research system enhanced by the Initiative for Excellence and Pact for Research and Innovation	- Impulses to modernise the non-university public research organisations not strong enough to bring about significant changes

Chapter 5. Knowledge circulation

The purpose of this chapter is to analyse and assess how the research system ensures appropriate knowledge flows and sharing between actors. This is vital for its further use in the economy and society or as the basis for subsequent advances in knowledge production. Knowledge circulation is expected to happen naturally to some extent, due to the mobility of knowledge holders, e.g. university graduates who go on to work in industry, and the comparatively low cost of reproducing knowledge once it is codified. However, there remain three challenges related to specific barriers to knowledge circulation which need to be addressed by the research system in this domain:

- Facilitating knowledge circulation between university, PRO and business sectors
- Profiting from access to international knowledge
- Enhancing the absorptive capacity of knowledge users

Significant elements of Integrated Guideline 7 relate to knowledge circulation. To address them effectively requires a good knowledge of the system's responses to these challenges.

5.1 Analysis of system characteristics

5.1.1 Facilitating inter-sectoral knowledge circulation

Given its technology-based economy, there is a long tradition of knowledge circulation between knowledge creators and knowledge users in Germany, and the process is supported by a range of institutional and programme-based measures. Cooperation between industry and the science system is highly institutionalised, with a range of intermediaries and two core institutions. From the applied research side, the Fraunhofer Society has a strong reputation for applied research in collaboration with industry. Of its annual research budget of over €1 billion, around €600 million comes from contracts with industry and from publicly financed collaborative research projects. One third is contributed institutionally by the German federal and *Länder* governments. From the industry side, the main institution in this field is the German Federation of Industrial Cooperative Research Associations "Otto von Guericke" (AiF), a non-profit association that aims to promote applied Research and Development (R&D) for the benefit of small and medium-sized enterprises (for details, see section 5.1.3 below).
Furthermore, the *Fachhochschulsystem* (according to the ERAWATCH Research Inventory, more than half of the German universities are what are called universities of applied sciences) is geared strongly towards knowledge circulation and education; thus, even if the research content has been improved over the last few years with the help of designated BMBF programmes, it remains somewhat limited. As most of the teaching staff of the *Fachhochschulen* have business experience and work on practical (often S&T) issues, they usually have close ties with regional industry and most graduates are able to find work locally.

Besides the institutional settings, nearly all R&D programmes managed by the BMBF and BMWi, as well as regional R&D programmes, include a strong focus on knowledge circulation between the public R&D system and the private sector, either as a separate set of projects within the overall programme or as an intrinsic element

of all the projects funded under one scheme. The increasing focus on networking and cluster programmes described in section 4 should be also seen as a driver for improved knowledge circulation between knowledge creators and knowledge users in general. One of the main aims of the BMWi's more innovation-oriented funding programmes is to enhance science-industry relations. Examples are the ProInno initiative and the "Promotion of Innovative Networks (InnoNet)" Programme, which is used to support the development of research networks comprising both small and medium-sized enterprises and research institutions.
Increasing circulation of knowledge between sectors is also an important focus of the work and the programmes of the *Stifterverband* (see also section 5.2.2). For example, most industry associations that are active in research launch PhD or post-Doc grant programmes via the *Stifterverband* and are regularly informed about the progress of the researchers funded.

Another more recent change in incentives is the change in the universities' IPR regime in 2002 so as to give the universities greater control over the intellectual property their researchers produce; this is modelled on the approach pioneered in the *Bayh-Dole Act* in the United States. This scheme is accompanied by the creation of transfer offices (*Patentverwertungsagenturen*) in most of the regions. The final impact of these measures is as yet unclear – on the one hand, it improves the visibility of value creation in public research, but on the other hand it might put a brake on the willingness of the private sector to cooperate with universities, if the universities themselves are too focused on using the research results to generate additional income. The US example has shown that funding of university research by the private sector has decreased significantly since the adoption of the Bayh-Dole act. A group of experts under the "partner for innovation" initiative sees a clear need to improve the business models of the transfer offices (Hoefer and Wengel, 2005).

The strength of inter-sectoral circulation of knowledge between science and industry, which is also highlighted in assessments (e.g. BMBF, 2006b), is to a certain degree also reflected in commonly used indicators. At 13.2%, the share of HERD financed by industry is nearly double the EU 27 average of 6.7% (2004). The share of GOVERD financed by industry was 2.9% (2004), which was significantly below the EU 27 average of 6.1%, although it grew strongly at over 8% per year between 2001 and 2004. However, this low share is more a reflection of the particular specialisation and organisation of the German non-university research system, where the Max Planck Society plays a strong role which has no parallel in other countries, and which dominates the substantial industry funds to the Fraunhofer Society, than a reflection of general weakness in the circulation of knowledge[3]. Moreover, in the German tradition of partly government-funded collaborative research projects inter-sectoral collaboration is not necessarily accompanied by inter-sectoral flows of funding.
The remaining weaknesses stressed in the system assessments relate rather to insufficient circulation of knowledge between the four pillars of the non-university public research system (HGF, MPG, FhG, WGL) and universities. This kind of knowledge circulation is less organised and does not perform as well, mainly owing to the diversity of topics covered in each of the organisations and their different missions. Knowledge circulation between the university system and the non-university system has been made the focus of a range of measures aimed at

[3] Early 2008, Eurostat data for Germany for this indicator has been substantially revised due to a new national calculation method since 2005. The corresponding value for Germany for 2005 is now 9.9%.

bolstering knowledge circulation, such as the joint appointment of HGF institute directors and university professors, and exchanges of PhD students.

5.1.2 Benefiting from access to international knowledge

German firms tend more to be 'first followers' rather than 'first movers', which means that access to international knowledge is crucial. The country's export surpluses in medium-to-high tech products would suggest that this strategy is successful. The strong reputation of German universities and companies worldwide gives them ready access to international knowledge. About 25% of private sector R&D in Germany is carried out by foreign affiliates and about 20% of R&D contracts from German companies go outside the country (Belitz, 2006).

Moreover, Germany's participation in the EU Framework Programme reveals a well developed network of connections. It is responsible for about 16% of all participants, equivalent to about 3 900 German organisations (although there may be some double counting here), including public organisations, companies and others. Usually, however, there is no direct national co-funding of applications to the Framework Programme. An exception is the contribution to the preparation of large projects as co-ordinator.

Scientific collaboration with other countries has a long tradition in Germany. Bilateral agreements on R&D cooperation are in place with more than 50 countries. A number of institutions are active in promoting and funding exchange programmes and/or grants for foreign researchers in Germany or for German researchers elsewhere. The most prominent institutions are the German Academic Exchange Service (DAAD), the Alexander von Humboldt Stiftung and the agency *Invent*. Also, the DFG runs a number of programmes aimed at strengthening international research cooperation. Instruments include funding the participation of German researchers in international conferences and a joint DFG/NIH programme for PostDocs, as well as bilateral cooperation agreements. Most of the non-university research pillars, such as the HGF, MPG, FhG and WGL, have offices outside Germany in order to stimulate international cooperation although there still remain problems related to their internationalisation (for details see Edler, 2007).

As Germany has a relatively big 'internal science market', there is a certain language barrier in fields such as the social sciences or law where language plays an important role in formalising scientific ideas. As a result, there are a number of journals in German which are not well connected to the outside world. The language barrier also limits the effectiveness of the degree of openness of a range of national research programmes, in which the funding of foreign participants via subcontracts is to a certain extent possible. The current transition from the university degree system towards a bachelor and master system will improve compatibility with key partner countries both within and outside the EU.

Government agencies are seeking a strategy to incorporate internationalisation, but until the publication of an internationalisation strategy early 2008 there has been no coherent strategy which highlights how international (mainly European) opportunities match national strengths and political priorities and how this could/should evolve.

While assessments of the system stress the fact that, generally speaking, the German innovation system is internationally well-connected (BMBF, 2006b), the system evaluations of the public research institutions have revealed considerable room for improvement as regards the international dimension of research (e.g. Wissenschaftsrat, 2001).

5.1.3 Enhancing the absorptive capacity of knowledge users

In general, the absorptive capacity, especially among SMEs, appears to be well developed, in view of the economy's basis in traditional technology and the high proportion of all enterprises (over 70%) that are engaged in innovation activities. Also, there are nearly 30 000 SMEs conducting their own R&D on a permanent basis; this is a high total, although for some time the total has been stagnating or even shrinking (Rammer, 2007). An important role in enhancing SME participation in R&D is played by the German Federation of Industrial Cooperative Research Associations "Otto von Guericke" (AiF). It is organised by industry along sectoral lines covering over 100 industrial research associations, including approximately 50,000 SMEs, and about 700 associated research institutions. The AiF lays the foundations for sector-specific industrial cooperative research in the pre-competitive stage and is organised by the industry itself. Since 2000, cross-sectoral interdisciplinary research in new technologies for the benefit of SMEs has also been supported under the ZUTECH programme. The work of the AiF is jointly financed by industry and the Federal government, via the BMWi budget.
Another noteworthy measure by the BMBF is the bottom-up initiative *www.kompetenznetze.de,* which is a forum for presentation of more than 100 networks.

Highly qualified scientists and engineers are often recruited by the private sector following joint projects. This is especially true of the *Fachhochschulen* (universities of applied sciences), where training in a private sector company for two six-month periods during studies is compulsory. The percentage of scientists and engineers in the total labour force - at 6.6% (2006) – is significantly higher than the EU average of 5.4%. The downward trend in the number of S&T graduates (see section 2.1.3) puts this strong position in danger. In the CIS 3 survey, one quarter of responding German companies gave ‘lack of qualified personnel’ as an important hampering factor; this is the highest proportion in the EU. The BMBF (2005) emphasises that the share of all new entrants to universities in mathematics, natural sciences and engineering rose considerably between 1998 and 2004. This will enhance the stock of S&T graduates, provided the number of entrants can be translated into corresponding numbers of graduates, which is not the case at the moment.

Rammer (2007) concludes in his assessment of the coherence of the policy mix that the specific problem of the decreasing share of SMEs performing R&D highlights the only major gap between the challenges and the instruments in place to respond to them in Germany. There are only a few measures that help non-R&D performing enterprises to take up R&D activities, and those that are in place, like the ProInno programme of the BMWi, reach only a limited number of firms and have a low quantitative effect. However, it is debatable whether simply focusing on supporting R&D activities in SMEs is a sufficiently targeted response, because sectoral differences are important. In new sectors, the actual challenge might be about supporting new, R&D-intensive firms, which is tackled to some degree, whereas in other established sectors involvement in capital investments plays a more central role, and alternative policy measures focusing on the upgrading of human resources, such as 'life-long learning' programmes, might be also important.

5.2 Analysis of recent changes and policy initiatives

5.2.1 Relevant recent trends

The increasing circulation of international knowledge as such is not a new phenomenon for Germany. What is relatively new is a stronger perception of possible costs such as the outsourcing of R&D to lower-cost locations with a high potential of well-qualified researchers, and a growing tendency of talented researchers to move to other locations, especially the US (Rammer, 2007).

5.2.2 Role and expected impact of recent policies

The National Reform Programme confirmed the importance attached to policy goals in the field of knowledge circulation, mentioning knowledge and technology transfer, the support of clusters and regional support for science-industry links as the first three innovation- and technology-related goals (Bundesregierung, 2005).
The High-Tech Strategy announced the launch of new measures that are basically aimed at increasing knowledge circulation and cooperation between science and industry. These measures frequently build on proposals of the "Partners for Innovation" initiative (see, for example, Hoefer and Wengel, 2005). The proposed measures include exchanges of staff between the public and the private research sectors and a competition for the award of grants for exchanges between universities and business, for which the first laureates were selected in early 2007. Both initiatives are managed jointly by the BMBF and the *Stifterverband.* Also, the new and reinforced cluster initiatives which were already described (see section 4.2.2) and the Research Union Economy – Science, (see section 3.2.2), aim at ensuring a better circulation of knowledge. With regard to the international circulation of knowledge, the High-Tech Strategy sees the international dimension as one of the five cross-cutting priorities, but remains rather vague about the specifics of the new measures. As part of the Six Billion Euro Programme, the German Foreign Ministry has received additional €100 million to foster international research cooperation.

A new measure that was already the subject of intensive discussion even before the publication of the High-Tech Strategy and was then integrated and implemented in early 2007 is the new "Research Grant" (*Forschungsprämie).* The principal aims of this measure are to facilitate the co-operation of public research institutions with business, in particular small and medium-sized enterprises, to enhance the economic use of scientific research results and to target public research more strongly at business needs. Universities and research organisations which are jointly financed by the federal state and the regions are offered an additional grant of 25% of the value of the research contracts they carry out on behalf of enterprises. The requirements include the following: the firms must have less than 1000 employees and the research must not have received public funding. There is a minimum volume of €10,000 and a support ceiling of €100,000 per contract. The grant can be used by the beneficiaries for orienting knowledge and technology transfer according to demand, for implementing measures to exploit R&D results, for strengthening the competencies of researchers to improve mobility towards the private sector and for improving the management of co-operation with industry. The grant may not be used for financing R&D on behalf of industry or for economic activities. The duration is limited to three years and there is provision for a parallel evaluation (BMBF, 2007b). A total budget of €100 million is earmarked. However, with this form of

implementation the Research Grant is not oriented towards a main system weakness (see also BMBF 2007a).
As an alternative to the Research Grant, there was a brief discussion in 2006 on the re-introduction of fiscal incentives for business R&D to reach a wider set of firms; however, this idea was discarded, citing prior negative experiences (see section 2.1.3). However, with the political agreement on the main lines of a general corporate tax reform in early 2007 that includes depreciation options and flexibility mechanisms relevant for R&D, renewed calls are being made for specific tax incentives for R&D (BMBF 2007b).

5.3 Assessment of knowledge circulation

The main strengths and weaknesses of the German research system in terms of knowledge circulation can be summarised as follows:

STRENGTHS:	WEAKNESSES:
- Broad R&D base in the private sector ensuring good absorptive capacity - High profile of knowledge circulation measures - Number of measures and institutions in place to ensure access to international knowledge	- Weak dynamics of absorptive capacity with regard to new private research performers and the availability of S&T graduates

The main opportunities and threats for knowledge circulation in Germany arising from recent policy responses and in the light of the Lisbon Strategy can be summarised as follows:

OPPORTUNITIES:	THREATS:
- Further improvement of the circulation of knowledge between sectors through new measures and governance mechanism targeting co-operation between PRO and industry, which may also counterbalance negative effects of the changed IPR regime	- Lack of an appropriate strategy response to the increased importance of European and international knowledge circulation - Policy measures too strongly oriented towards knowledge circulation between established research organisations and firms

Chapter 6. Overall assessment and conclusion

6.1 Strengths and weaknesses of research system and governance

The analysis has shown that Germany has a highly developed and well functioning research system. In each of the main domains there are strong system responses to the domain challenges (see also the summary assessment table below). Very often the responses take the form of quite stable institutional arrangements, such as the role of the German Science Foundation and the German Science Council in enhancing quality and excellence of knowledge production, or the Fraunhofer Society and the AIF in enhancing knowledge circulation to the economic sector. Any remaining weaknesses are mostly related to the adaptation and enhancement of the changes being put in place, whether this be the extent of increases in financial resources or addressing signals of cross-cutting new demand and new scientific opportunities. They are partly a reflection of the strength of the established system responses.

Domain	Challenge	Assessment of system strengths and weaknesses
Resource mobilisation	Securing long-term investment in research	Stable mechanisms to ensure long-term research funding, but multi-level negotiations for increases are time-consuming and require political majorities difficult to achieve
	Dealing with barriers to private R&D investment	The two-thirds share of private R&D funding meets Lisbon objectives
	Providing qualified human resources	Functioning mechanisms for the provision of a strong human resource base for R&D with declining S&T graduate basis but increased attractiveness of research careers
	Justifying resource provision for research activities	Well established justification in terms of preserving economic competitiveness through S&T did not prevent declining share of R&D expenses in general budget
Knowledge demand	Identifying the drivers of knowledge demand	Demand signals from classical industries well perceived by policies, but demand signals outside of these or international demand signals not well addressed
	Channelling knowledge demands	Strong R&D programme basis enables a flexible response to changes in demand
	Monitoring demand fulfilment	Well established evaluation mechanisms enable responses to changes in demand
Knowledge production	Ensuring quality and excellence of knowledge production	Mechanisms in place to enhance scientific excellence of public research through DFG and Science Council. However, the rigidity of the public research system, which is strongly geared towards traditional scientific disciplines, makes it difficult to adapt to cross-cutting opportunities
	Ensuring exploitability of knowledge	Strong focus on research closely linked to the economy's strengths
Knowledge circulation	Facilitating circulation between the different research sectors	High profile of knowledge circulation measures
	Profiting from international knowledge	Number of measures and institutions in place to ensure access to international knowledge
	Enhancing the absorptive capacity of knowledge users	Broad R&D base in the private sector ensuring good absorptive capacity, but weak dynamics with regard to new private research performers and S&T graduates

The governance structure reflects the high level of development and differentiation of the German research system (see also the related positive appraisal of the German innovation governance by the European Trend Chart on Innovation, 2006). The only area in which system weaknesses are closely related to the governance structure as such is the complicated co-ordination of resource mobilisation in a federal system with shared responsibilities.

6.2 Policy dynamics, opportunities and threats from the perspective of the Lisbon agenda

The following overview table presenting an assessment of main opportunities and threats related to recent policy dynamics shows that recent policies, such as the Six Billion Euro programme, the High-Tech Strategy and the Initiative for Excellence, address some of the main weaknesses of the German research system and hence contribute to opportunities for its further evolution. Most aspects of the research-related Integrated Guideline of the Lisbon Strategy are addressed, from the 3% R&D intensity target, via the strengthening of centres of excellence and the reform of the

public research base to the improvement of co-operation between PRO and industry. The extent of the effects of recent policies remains to be seen.
Main threats are in particular related to the domains of resource mobilisation, in which both public and private R&D funding are still insufficient to meet the 3% target, and the domain of knowledge circulation. Here weaknesses like the seemingly stagnating absorptive capacity and trends that have recently gained importance, such as the Europeanisation and internationalisation of knowledge production and circulation, are only partly addressed by recent policy measures.

Domain	Main policy-related opportunities	Main policy-related threats
Resource mobilisation	- Increased volume and greater political focus on public resource mobilisation through the federal "Six billion Euro programme"	- Public resource mobilisation, in particular at the Länder level, is insufficient to meet the Lisbon target - Private resource mobilisation might not respond to increased incentives to the extent anticipated
Knowledge demand	- More effective knowledge demand through better coordination between federal actors and more holistic approaches via the High-Tech Strategy	
Knowledge production	- Improved excellence and increased international attractiveness of public research, enhanced by the Initiative for Excellence and Pact for Research and Innovation	- Impulses to modernise the non-university public research organisations not strong enough to bring about significant changes
Knowledge circulation	- Further improvement of the circulation of knowledge between sectors through new measures and governance mechanism targeting co-operation between public research organisations and industry, which may also counterbalance negative effects of the changed regime of intellectual property rights	- Lack of an appropriate strategy response to the increased importance of European and international knowledge circulation. - Policy measures too strongly oriented towards knowledge circulation between established research organisations and firms

The analysis of recent policies in these domains has shown that current German research policy priorities correspond by and large to the strengths and weaknesses of the research system. As might be expected in highly developed research systems, issues of cross-domain integration play a more prominent role and are increasingly effectively addressed by the research policy mix. Examples include recent policy initiatives such as the Excellence Initiative, the High-Tech strategy and the Pact for Research and Innovation, all of which systematically link increased resource mobilisation to improvements in demand articulation, knowledge production and knowledge circulation. This is partially underpinned by new governance mechanisms like the Research Union Economy – Science which is intended to contribute to the monitoring of the High-Tech Strategy. Another indicator of a cross-domain perspective is the frequency of cluster approaches as part of the policy measures.

The increased importance of the context of the European Research Area is acknowledged by research policy makers, e.g. in the High-Tech Strategy, and German actors are actively involved in shaping the ERA. However, it is not yet operational on the political level. The responses, in the form of the internationalisation strategy which has finally been released early 2008, are awaited.

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Abbreviations

AiF: Arbeitsgemeinschaft industrieller Forschungsvereinigungen "Otto von Guericke" (German Federation of Industrial Research Associations)

BLK: Bund-Länder Kommission für Bildungsplanung und Forschungsförderung (Bund-Länder Commission for Educational Planning and Research Promotion)

BMBF: Bundesministerium für Bildung und Forschung (Federal Ministry of Education and Research)

BMWA: Bundesministerium für Wirtschaft und Arbeit (Federal Ministry of Economics and Labour)

BMWI: Bundesministerium für Wirtschaft und Technologie (Federal Ministry of Economics and Technology)

DAAD: Deutscher Akademischer Austauschdienst (German Academic Exchange Service)

DFG: Deutsche Forschungsgemeinschaft (German Research Foundation)

FhG: Fraunhofer Gesellschaft (Fraunhofer Society)

GWK: Gemeinsame Wissenschaftskonferenz (Joint Science Conference)

HGF: Helmholtz-Gemeinschaft Deutscher Forschungszentren (Helmholtz Association)

MPG: Max Planck Gesellschaft (Max Planck Society)

WGL: Wissenschaftsgemeinschaft Gottfried Wilhelm Leibniz (Leibniz Association)

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Abstract

The main objective of ERAWATCH analytical country reports is to characterise and assess the performance of national research systems and related policies in a structured manner that is comparable across countries. The reports support the mutual learning process and the monitoring of Member States efforts by DG Research in the context of the Lisbon Strategy. In order to do so, the system analysis focuses on key processes relevant for system performance. Four policy-relevant domains of the research system are distinguished, namely resource mobilisation, knowledge demand, knowledge production and knowledge circulation. This analytical approach has been tested in 2007 by applying it to six countries, one of which is Germany. The report is based on a synthesis of information from the ERAWATCH Research Inventory and other important available information sources.